

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>C12Q 1/42, G01N 33/50, 33/58, A61P 9/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/39328</b> <b>(43) International Publication Date:</b> 6 July 2000 (06.07.00)
<b>(21) International Application Number:</b> PCT/US99/29845 <b>(22) International Filing Date:</b> 15 December 1999 (15.12.99) <b>(30) Priority Data:</b> 09/220,913 24 December 1998 (24.12.98) US <b>(71) Applicant:</b> THE GENERAL HOSPITAL CORPORATION [US/US]; 55 Fruit Street, Boston, MA 02114 (US). <b>(72) Inventor:</b> HAUPERT, Garner, T., Jr.; 512 Great Road, Littleton, MA 01460 (US). <b>(74) Agents:</b> PIERCE, N., Scott et al.; Hamilton, Brook, Smith & Reynolds, P.C., Two Militia Drive, Lexington, MA 02421 (US).		<b>(81) Designated States:</b> CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> SCREENING FOR HIF LIKE OUABAIN-RESISTANT Na <sup>+</sup> -K <sup>+</sup> -ATPASE AGENTS		
<b>(57) Abstract</b>  The present invention relates to rapid, quantitative, specific, high through-put methods for screening test substances for their ability to inhibit activity of an ouabain-resistant Na <sup>+</sup> -K <sup>+</sup> -ATPase involved in a variety of biological processes such as regulation of osmotic balance and cell volume, maintenance of the resting membrane potential, establishment of the ionic composition of cerebrospinal fluid and aqueous humor, electrical activity of muscle and nerve, and receptor-mediated endocytosis, cardiac muscle contractility, neurotransmitter metabolism and vascular muscle cell contraction. These methods can be employed to identify compounds for use in therapeutic applications for disease processes in which dysfunction of the Na <sup>+</sup> -K <sup>+</sup> -ATPase contributes to a pathological process. The present invention also includes kits which are used in the methods provided herein. The present invention further includes methods of treating or preventing diseases or disorders which are associated with dysfunction of the Na <sup>+</sup> -K <sup>+</sup> -ATPase.		

AP

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

-1-

SCREENING FOR HIF LIKE OUABAIN-RESISTANT  $\text{Na}^+\text{-K}^+\text{-ATPase}$  AGENTS

## BACKGROUND OF THE INVENTION

$\text{Na}^+\text{-K}^+\text{-ATPase}$  is a plasma membrane-associated enzyme which is encoded by a multigene family. Activity of the  $\text{Na}^+\text{-K}^+\text{-ATPase}$  provides gradients of  $\text{Na}^+$  and  $\text{K}^+$  that are essential for maintaining cellular homeostasis. (Levenson, *Rev. Physiol. Biochem. Pharmacol.* 123:1-45, 1994). The ion gradients established by the  $\text{Na}^+\text{-K}^+\text{-ATPase}$  play a central role in regulating osmotic balance, cell volume, and maintaining the resting membrane potential.  $\text{Na}^+$ -coupled transport of nutrients, establishment of the ionic composition of cerebrospinal fluid and aqueous humor, electrical activity of muscle and nerve, and receptor-mediated endocytosis are all processes which depend on the activity of the enzyme.

Compounds have been identified that inhibit  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , and at least some of these compounds, plant-derived cardiac glycosides like ouabain and digoxin, have found therapeutic utility, such as treatment of congestive heart failure. However, ouabain can also have deleterious side effects that have not been associated with the use of an endogenous compound, hypothalamic inhibitory factor (HIF), which also has been found to have an inhibitory effect on  $\text{Na}^+\text{-K}^+\text{-ATPase}$ .

Sensitivity of the  $\text{Na}^+\text{-K}^+\text{-ATPase}$  to ouabain and HIF lies within the  $\alpha$  subunit of the enzyme. To date, all  $\alpha 2$  and  $\alpha 3$  isoforms and  $\alpha 1$  isoforms from most mammals and other organisms tested are sensitive to ouabain, i.e., can be inhibited at relatively low ouabain concentrations. However, certain  $\alpha 1$  isoforms are resistant to ouabain.

A need exists to identify other inhibitors of  $\text{Na}^+\text{-K}^+\text{-ATPase}$  which, like HIF, will have fewer potential side-effects than ouabain, and related cardiac glycosides obtained from plants.

## SUMMARY OF THE INVENTION

The present invention is directed to methods and kits for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  and for treating or preventing diseases or disorders with substances identified by the screening methods described herein.

In one embodiment, the method includes contacting an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with a test substance under conditions suitable for measuring or detecting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity. The ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  inhibitory activity of the test substance is measured or detected. The level of activity of the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  measured or detected in the presence of the test substance is then compared with the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity measured or detected in the presence of HIF under comparable conditions. thereby determining whether the test substance exhibits HIF inhibitory activity.

In another embodiment, the method includes contacting the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with a test substance in the presence of ATP and a non-ATP substrate, under conditions suitable for measuring or detecting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity. Oxidation of the non-ATP substrate is measured or detected to determine the ATPase activity. This activity is compared to the activity measured or detected using again the oxidation of a non-ATP substrate contacted with ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  and ATP in the presence of HIF under comparable conditions. thereby determining whether the test substance exhibits HIF inhibitory activity.

In still another embodiment, the method includes contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with a test substance in the presence of ATP, wherein the terminal phosphate ( $\text{P}_3$ ) is labeled, under conditions suitable for measuring or detecting liberated labeled  $\text{P}_3$ . Labeled  $\text{P}_3$  liberated from the ATP substrate is measured or detected. The measured or detected liberated labeled  $\text{P}_3$  is compared with measured or detected labeled  $\text{P}_3$  liberated by contact of ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF in the presence of ATP, wherein the terminal phosphate is labeled. and under comparable conditions, thereby determining whether the test substance exhibits HIF activity.

-3-

In a further embodiment, a liposome containing, or a cell containing or expressing, ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is contacted with a test substance in the presence of a compound comprising  $\text{Rb}^+$ , under conditions suitable for isotopic  $\text{Rb}^+$  uptake by the liposomes or the cells. The amount of isotopic  $\text{Rb}^+$  present in the liposomes or cells is compared with isotopic  $\text{Rb}^+$  measured or detected in liposomes or cells obtained by contacting liposomes containing, or cells containing or expressing, ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF in the presence of a compound comprising isotopic  $\text{Rb}^+$ , under comparable conditions, thereby determining whether the test substance exhibits HIF inhibitory activity.

10 A kit of the invention includes an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , or reconstituted liposomes or cells containing or expressing, an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ . The kit also includes HIF, a non-ATP substrate, ATP or labeled ATP, and a compound containing isotopic  $\text{Rb}^+$ .

In another embodiment, the kit includes an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , ATP, NADH and HIF.

15 In a further embodiment, the kit includes an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , ATP in which the  $\text{P}_\beta$  is labeled and HIF.

In yet another embodiment, the kit includes reconstituted liposomes containing, or cells containing or expressing, ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , a compound containing isotopic  $\text{Rb}^+$  and HIF.

20 A method of the invention treats or prevents a disease or disorder by administering, to a subject to whom such treatment or prevention is in need thereof, an effective therapeutic amount of a biologically active substance identified by any of the methods described herein for screening a test substance as exhibiting HIF inhibitory activity.

25 The present invention encompasses rapid, quantitative, specific, high through-put methods for screening test substances such as drugs, ligands (natural or synthetic), ligand antagonists, peptides, small organic molecules and the like, for their ability to inhibit activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  involved in a variety of

-4-

biological processes. Examples of such biological processes include the regulation of osmotic balance and cell volume, maintenance of the resting membrane potential, establishment of the ionic composition of cerebrospinal fluid and aqueous humor, electrical activity of muscle and nerve, and receptor-mediated endocytosis, cardiac muscle contractility, neurotransmitter metabolism and vascular muscle cell contraction. Identification of other substances that, like HIF, inhibit ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase, may lead to treatment or prevention of disorders or diseases without the side effects characteristic of ouabain.

#### DETAILED DESCRIPTION OF THE INVENTION

10 The features and other details of the invention will now be more particularly described and pointed out below and in the claims. It will be understood that the particular embodiments of the invention are shown by way of illustration and not as limitations of the invention. The principle features of this invention can be employed in various embodiments without departing from the scope of the invention.

15 The present invention is directed to methods and kits for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase and for treating or preventing diseases or disorders with substances identified by the screening methods described herein. It is believed that other compounds which, like HIF, inhibit ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase may also share a low toxicity profile.

20 Sensitivity of  $\text{Na}^+\text{-K}^+$ -ATPase to ouabain and hypothalamic inhibitory factor (HIF) lies within the  $\alpha$  subunit of the enzyme. However, certain  $\alpha_1$  isoforms isolated from rats, mice, species of amphibians such as the toad *Bufo marinus*, and species of butterflies such as the Monarch butterfly *Danaus plexippus*, are resistant to ouabain (Levenson R., *Rev. Physiol. Biochem. Pharmacol.*, 123:1-45, 1994; Holzinger *et al.*, *FEBS* 314:477-480, 1992; and Jaisser *et al.*, *J. Biol. Chem.* 267:16895-16903, 1992). In order to inhibit these ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPases, a 100 fold or higher concentration of ouabain than that capable of inhibiting ouabain sensitive  $\text{Na}^+\text{-K}^+$ -ATPase generally is needed. In addition, a number of mutations have been found to be

able to convert an ouabain-sensitive  $\text{Na}^+\text{-K}^+\text{-ATPase}$  into an ouabain-resistant one (Lingrel *et al.*, *The Sodium Pump* (Bamberg and Schoner, Ed.) pp. 276-286, 1994). Most of these mutations are located within the extracellular domains or at the borders of the extracellular domains. While inactivation of the ouabain-resistant  $\alpha_1$  isoform  
5 (obtained from rat kidney) requires concentrations of ouabain  $10^2\text{-}10^3$  greater than that for inactivating the ouabain-sensitive  $\alpha_2/\alpha_3$  isoforms (obtained from rat brain axolemma) (Sweadner, *Biochem. Biophys. Acta.* 988:185-220, 1989), such is not the case for hypothalamic inhibitory factor (hereinafter HIF). Ferrandi and co-workers isolated HIF from bovine and rat hypothalamus (Ferrandi *et al.*, *Am. J. Physiol.*  
10 263:F739-F748, 1992), and discovered that HIF could inhibit ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  at physiological dosages.

In one embodiment of the present invention, an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is contacted with a test substance under suitable conditions. An example of a suitable medium is an aqueous medium for which the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$   
15 is active (Sweadner, K., *J. Biol. Chem.*, 260:11508-11513, 1985).

Ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  proteins and nucleic acids can be obtained by methods known in the art. The ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can be derived, isolated or obtained from various target cell types. Examples of target cell types include, but are not limited to, kidney, heart, pineal gland, skeletal muscle, retina  
20 horizontal. retina Muller cells, brain cortical astrocytes, cerebellar granule neurons, cortical neurons and Hippocampal neurons. In a specific embodiment, the target cells are derived, isolated or obtained from a patient exhibiting a disease state that is related to the dysfunction of the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  (Decollogne *et al.*, *The Sodium Pump*, Bamberg and Schoner (eds) pp. 812-815, 1994). Examples of the  
25 disease state include, but are not limited to, cardiac malfunctions such as congestive heart failure, paroxysmal atrial tachycardia or atrial fibrillation, edematous disorders such as congestive heart failure, cirrhosis of the liver and nephrotic syndrome, and hypotension. In a specific embodiment, the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is derived from a rodent, an amphibian or a butterfly species. For example, a suitable ouabain-

-6-

resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can be derived from a mouse, a rat, a toad *Bufo marinus* or a Monarch butterfly *Danaus plexippus*. Alternatively, the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can be obtained by converting or mutating an ouabain-sensitive  $\text{Na}^+\text{-K}^+\text{-ATPase}$  into an ouabain-resistant one. The ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can be obtained by  
5 changing or substituting one or both border amino acid residues of the H1-H2 extracellular domain of  $\alpha$  subunit of an ouabain-sensitive  $\text{Na}^+\text{-K}^+\text{-ATPase}$  to a charged amino acid residue, including a positively or negatively charged amino acid. Additional examples of mutations that confer ouabain resistance to an otherwise ouabain-sensitive  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is disclosed in Lingrel *et al.*, *The Sodium Pump* (Bamberg and Schoner,  
10 Ed.) pp.276-286, 1994. The nucleotide sequence for rat, butterfly Monarch *Danaus plexippus* and toad *Bufo marinus*  $\alpha 1$   $\text{Na}^+\text{-K}^+\text{-ATPase}$  is disclosed in Shull *et al.*, *Biochemistry* 25:8125-8132, 1986; Jaisser *et al.*, *J. Biol. Chem.* 267:16895-16903, 1992 and Holzinger *et al.*, *FEBS* 314:477-480, 1992, respectively.

Cells of animal origin, particularly, rodent species such as mouse or rat,  
15 amphibians such as toad *Bufo marinus* and butterfly species such as Monarch butterfly *Danaus plexippus* can serve as a nucleic acid source for the isolation of  $\alpha$  isoforms of  $\text{Na}^+\text{-K}^+\text{-ATPase}$  nucleic acids. The DNA can be obtained by standard procedures known in the art from cloned DNA (e.g., a DNA "library"), chemical synthesis, cDNA cloning, or by the cloning of genomic DNA, or fragments thereof, purified from the  
20 desired cell (see, for example, Sambrook *et al.*, 1989, *Molecular Cloning, A Laboratory Manual*, 2d Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, *DNA Cloning: A Practical Approach*, MRL Press, Ltd., Oxford, U.K. Vol. I, II. Clones derived from genomic DNA can contain regulatory and intron DNA regions in addition to coding regions; clones derived from cDNA or RNA  
25 contain exon sequences. Whatever the source, the gene is generally molecularly cloned into a suitable vector for propagation of the gene.

In the molecular cloning of the gene from cDNA, cDNA can be generated from totally cellular RNA or mRNA by methods that are known in the art. The gene can also be obtained from genomic DNA, where DNA fragments are generated (e.g. using



-7-

restriction enzymes or by mechanical shearing), some of which will encode the desired gene. The linear DNA fragments can then be separated according to size by standard techniques, including but not limited to, agarose and polyacrylamide gel electrophoresis and column chromatography.

- 5        Once the DNA fragments are generated, identification of the specific DNA fragment containing all or a portion of the Na<sup>+</sup>-K<sup>+</sup>-ATPase gene can be accomplished in a number of ways known to those skilled in the art (Sambrook et al., 1989, *Molecular Cloning, A Laboratory Manual*, 2d Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, *DNA Cloning: A Practical*  
10 *Approach*, MRL Press, Ltd., Oxford, U.K. Vol. I, II; Shilo and Weinberg, 1981, *Proc. Natl. Acad. Sci. USA* 78:6789-6792).

- Ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase proteins and derivatives, analogs and fragments thereof can be obtained by methods known in the art, including but not limited to, recombinant expression methods, purification from natural sources, and  
15 chemical synthesis (Sambrook et al., 1989, *Molecular Cloning, A Laboratory Manual*, 2d Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, *DNA Cloning: A Practical Approach*, MRL Press, Ltd., Oxford, U.K. Vol. I, II; Shilo and Weinberg, 1981, *Proc. Natl. Acad. Sci. USA* 78:6789-6792).

- The test substance that is contacted with the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase  
20 by the method of the invention can be a chemical compound, such as organic molecules, inorganic molecules, organic/inorganic molecules, proteins, peptides, polysaccharides, saccharides, glycoproteins, nucleic acid strands or oligonucleotides like deoxyribonucleic acid (hereinafter "DNA") and ribonucleic acid (hereinafter "RNA"), or mixture of compounds like in the case of a library of test substances, a natural extract or  
25 tissue culture extract, whose effect on an ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase is determined by one or more of the methods described herein. The test substance can be an organic molecule, such as a steroid, cardiac glycoside or structurally similar compound, or a combinatorial library of such compounds. Ouabain itself is not considered a "test substance" as that term is used herein.

Activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is measured or detected by methods known in the art, which methods include, but are not limited to, coupled-enzyme assays (Haupt, G. *et al.*, *Am. J. Physiol.*, 247:F919-F924, 1984), ATP hydrolysis assays (Doucet *et al.*, *Am. J. Physiol.*, 237(2):F105-F113, 1979), and ion transport assays (Cantiello *et al.*, *Am. J. Physiol.*, 255:F574-F580, 1988). The assay can be quantitative or qualitative.

The level of activity measured or detected for ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , when contacted with the test substance, is compared to the ATPase activity in the presence of HIF under comparable conditions.

10 HIF is isolated from mammalian organs, tissues or cell types containing HIF. In a specific embodiment, the HIF is isolated from hypothalamus (e.g., bovine hypothalamus) according to the procedures disclosed in U.S. Patent No. 5,716,937 or Tymiak *et al.*, *Proc. Natl. Acad. Sci. USA* 90:8189-8193, 1993.

HIF generally is attributed with having the following characteristics: 1) it is a regio-chemical or stereo-chemical isomer of ouabain; 2) it specifically and reversibly binds ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ; and 3) after naphtholylation, it yields a CD spectrum substantially different from that of ouabain, see U.S. Patent No. 5,716,937. It should be recognized that an HIF analogue, derivative, solvate or related compound having HIF inhibitory activity on an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can also be used, although it is ideal that HIF itself is used.

20 "Comparable conditions" according to the method of the invention are defined as the conditions of an assay conducted in substantially the same manner as a referent assay. That is to say, if an assay is to be the object of comparison (i.e., if a comparison of activity of the test substance is to be made to the activity of a reference compound such as HIF), then the assay of activity of the reference material would be the referent assay under conditions equivalent to, or the same as, conditions under which the activity of the test substance was assayed. The concentration(s) of the test substance used in methods described herein generally are equivalent or the same as that of the HIF. In comparing the activity of the test substance with that of HIF, a determination is made as

to whether the test substance inhibits the activity of the same ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase (e.g., rat kidney) to the same extent as HIF inhibitory activity.

“HIF inhibitory activity” is defined herein to mean the inhibition of the ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase exhibited by HIF. For example, a test substance can be  
5 determined to have HIF inhibitory activity if it inhibits the same ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase (e.g., rat kidney) to the equivalent or same degree as HIF at the equivalent or same concentration and under equivalent or the same conditions under which HIF exhibits inhibitory activity. In one embodiment, a positive result is found when the level of ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase activity measured when the ouabain-resistant  
10  $\text{Na}^+\text{-K}^+$ -ATPase is contacted with the test substance is the same as or less than that measured when the ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase is contacted with HIF under comparable conditions. A test substance that would be of particular interest can be one that exhibits, for example, from about the same to about ten times the HIF inhibitory activity.

15 In comparing the activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase (or “pump”) measured when the pump is contacted with a test substance with that when the pump is contacted with HIF, it is unnecessary to measure the activity of the ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase in parallel, although such parallel measurement is considered to be within the scope of the invention.

20 In another embodiment, ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase inhibitory activity can be measured or detected using a coupled-assay, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase is contacted with a test substance in the presence of ATP and a non-ATP substrate. More specifically, a test substance is preincubated in a buffer containing ouabain-resistant  $\text{Na}^+\text{-K}^+$ -ATPase and ATP. The preincubation is carried out in the  
25 presence of chelators such as norepinephrine, BSA, and EGTA to avoid interferences by ionic species present in the enzyme or HIF fractions, such as vanadate, free fatty acids, and bivalent cations. After preincubation, the incubating solution is added to a prewarmed reading solution containing buffering agents (physiological pH is used), ATP, and a non-ATP substrate, such as NADH. The enzymatic reaction is conducted at

-10-

a temperature where the enzyme is active, e.g. from about 25°C to about 40°C for a period of time where activity, if present, is detected for about 1 second to about 5 minutes or more. A more detailed description of this assay can be found in Hauptert, G., *et al.*, *Am. J. Physiol.*, 247:F919-F924, 1984.

- 5           In one embodiment, the non-ATP substrate is NADH which is oxidized to form NAD<sup>+</sup>. The oxidation of the non-ATP substrate and, thus, enzyme activity, is measured either by an increase of the amount (or accumulation) of the oxidized substrate, or a decrease of the amount (or depletion) of the non-ATP substrate. The oxidation reaction is monitored constantly, intermittently or finally by techniques known in the art. For
- 10   example, spectrophotometry can detect a decrease of the amount of the non-ATP substrate or an increase of the amount of the oxidized non-ATP substrate. The enzymatic activity can be calculated from the slope of the oxidation reaction. Enzymatic activity typically is expressed as  $\mu\text{mol}$  (of the decrease of the non-ATP substrate or the increase of the oxidized form of the non-ATP substrate)/ $\mu\text{g}$  protein/min.
- 15   In one particular embodiment, the inhibitory activity of the test substance is expressed as percent of the control sample assay, where the control sample assay is performed under the same conditions but in the absence of either the test substance or HIF. In one embodiment, the conversion of NADH to NAD<sup>+</sup> is measured by a decrease of the amount of the NADH. In another embodiment, the decrease of the amount of the
- 20   NADH is measured by a decrease in absorbance at 340 nm. An example of a suitable assay employing NADH can be found in Hauptert, G., *et al.*, *Am. J. Physiol.*, 247:F919-F924, 1984.

A comparison is then made between the measurement, or detection, of oxidation of the non-ATP substrate when the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase is in the presence

25   of the test substance with the measurement, or detection, of oxidation of the non-ATP substrate when the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase is in the presence of HIF, thereby determining whether the test substance exhibits HIF inhibitory activity.

In another embodiment, the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase is contacted with a test substance in the presence of ATP, wherein the terminal phosphate group (P<sub>3</sub>) is

-11-

labeled. The  $P_3$  of ATP is labeled in such a way that the label does not substantially interfere with the hydrolysis of ATP by the ouabain-resistant  $Na^+-K^+-ATPase$ . The label of the  $P_3$  is selected from, for example, the group consisting of a radiolabel, a fluorescent label, a luminescent label and an enzymatic label. In one embodiment, the  
5 labeled ATP is [ $^{32}P$ ]ATP.

In this embodiment, ouabain-resistant  $Na^+-K^+-ATPase$  activity can be measured by an ATP hydrolysis assay. Typically, a suitable ATP hydrolysis assay includes preincubating a test substance in a physiological buffer containing isolated ouabain-resistant  $Na^+-K^+-ATPase$ . Parallel experiments can be carried out in the presence of  
10 different buffer solutions or chelators during preincubation, such as norepinephrine, EDTA, EGTA, glutathione, mercaptoethanol, and BSA, to evaluate the ionic requirements for the binding of the test substance, and to determine if, in comparison to HIF, chelators interfere with the inhibitory activity of the test substance. After the preincubation period, the incubation solution containing ATP (in which  $P_3$  is labeled) is  
15 allowed to proceed for a sufficient time to cleave labeled  $P_3$  from [ $^{32}P$ ]ATP at a temperature, for example, in a range from about 25°C to about 37°C, and from about 2 to 30 minutes. The reaction is then terminated by, for example, the addition of perchloric acid, or some other suitable method.

The liberated, labeled  $P_3$  is then separated from the rest of the reaction mixture  
20 by a suitable separation technique, such as is known in the art. In one embodiment, the liberated labeled  $P_3$  is separated from the rest of the reaction mixture by centrifugation. In a specific embodiment, the liberated labeled  $P_3$  is separated from the rest of the reaction mixture by centrifugation in the presence of activated charcoal.

The amount of the liberated labeled  $P_3$  is measured. The amount of the liberated  
25  $^{32}P$  (or the amount of [ $^{32}P$ ]ATP remaining) can be measured by, for example, liquid scintillation counting. The inhibitory activity of the test substance and HIF is expressed as percent of the control sample; that is, the assay can be performed in the absence of either the test substance or HIF.

-12-

A comparison is then made between the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity in presence of the test substance with that of the ATPase activity incubating in the presence of HIF under comparable conditions. The comparison of activity between the two conditions is through the measurement or detection of liberated labeled  $\text{P}_i$ .

5 In another embodiment of the present invention, isotopic  $\text{Rb}^+$  is used in screening a test substance for HIF inhibitory activity. A screening method is used to examine the putative inhibitory effect of a test substance upon the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  by analyzing the uptake of the isotopic  $\text{Rb}^+$  into, for example, reconstituted liposomes containing, or cells expressing or containing, the ouabain-  
10 resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ . Examples of  $^{86}\text{Rb}^+$ -containing compounds include, but are not limited to,  $\text{Rb}^+$  salts, such as  $\text{RbCl}$ ,  $\text{RbBr}$  and  $\text{RbAc}$ . In a specific embodiment, the isotopic  $\text{Rb}^+$  is  $^{86}\text{Rb}^+$ . An example of a suitable assay employing isotopic  $\text{Rb}^+$  is described in Anner *et al.*, *Am. J. Physiol.*, 258:F144-F153, 1990.

Purified ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  can be reconstituted into  
15 phosphatidylcholine liposomes using methods in the art, such as the cholate-dialysis method disclosed by Anner and Moosmayer in *Biophys. Res. Commun.* 129:102-108, 1985. Cells containing ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , such as rat kidney cells, can be prepared by standard techniques known in the art (see, for example, Shyjan and Levenson, *Biochemistry* 28:4531-4535, 1989). To measure ion transport activity of the  
20 reconstituted liposomes containing, or cells containing or expressing, ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , freshly reconstituted liposomes or isolated cells are washed with a physiological solution and resuspended. A test substance is preincubated with the washed reconstituted liposomes or cells. After preincubation, a compound containing an isotopic  $\text{Rb}$ , such as  $^{86}\text{RbCl}$ , is added. The incubation is stopped after sufficient time.  
25 form about 1 to 5 minutes at about  $25^\circ\text{C}$  to about  $37^\circ\text{C}$ , to allow internal accumulation of  $^{86}\text{Rb}^+$ . The liposomes or cells are separated from the medium and the amount of isotopic  $\text{Rb}^+$  present in the liposomes or cells are counted. The inhibitory activity of the test substance and HIF is expressed as percent of the control sample, carried out in the absence of the test substance and HIF.

-13-

Rb<sup>+</sup> present in liposomes containing, or in the cells expressing or containing, the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase is separated from the unincorporated or liberated compound containing Rb<sup>+</sup> by a suitable separation technique, such as is known in the art. In one embodiment, the Rb<sup>+</sup> present in the cells is separated from the unincorporated or liberated compound containing Rb<sup>+</sup> by centrifugation through, for example, an oil layer, such as a phthalate oil layer. In another embodiment, the Rb<sup>+</sup> present in the liposomes is separated from the unincorporated or liberated compound containing Rb<sup>+</sup> by chromatography. In one embodiment, the amount of the <sup>86</sup>Rb<sup>+</sup> present in the liposomes or the cells is measured by a gamma counter.

10 A comparison is then made between the ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase activity incubated in presence of the test substance with that of the ATPase activity incubated in the presence of HIF under comparable conditions. The comparison of activity between the enzyme being incubated with the test substance versus HIF is made through the measurement or detection of <sup>86</sup>Rb<sup>+</sup> present in the liposomes or cells expressing or containing ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase.

15 Inhibitors of an ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase identified by the screening methods disclosed above can be employed to treat or prevent certain diseases or disorders, such as a cardiac malfunction, to produce a positive inotropic effect. Examples of disorders or diseases that can be treated by test substances identified by the method of the invention are taught in U.S. Patent No. 5,716,937. U.S. Patent No. 20 5,716,937 discloses methods of treating cardiac malfunction such as congestive heart failure, paroxysmal atrial tachycardia and atrial fibrillation. edematous disorders such as congestive heart failure, cirrhosis of the liver or nephrotic syndrome and hypotension. by administering a positive inotropic effect-producing glycosidic HIF. The inhibitors 25 identified by the invention can be isolated and/or prepared and incorporated into suitable pharmaceutical compositions by suitable methods. such as those known in the art. for oral, parenteral (or intravenous) delivery.

The present invention also includes kits which can be employed using the methods disclosed herein. In specific embodiments, kits of the invention can include all

-14-

or some of the following items: (a) an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  and/or reconstituted liposomes containing or cells containing or expressing an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ; (b) HIF; (c) a non-ATP substrate, such as NADH; (d) ATP and/or labeled ATP; and (e) a compound containing isotopic  $\text{Rb}^+$ .

- 5       The following are examples of specific embodiments of the invention described herein. They are intended to serve as illustrations and not limitations of the present invention.

### EXEMPLIFICATION

#### Example 1: *Coupled-enzyme Assay*

- 10        $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity is measured spectrophotometrically at about  $37^\circ\text{C}$  as a decrease in absorbance at 340 nm due to of the oxidation of NADH, as previously described (Hauptert *et al.*, *Am. J. Physiol.* 247:F919-F924, 1984).

- The test substance and HIF, typically in amounts of nanograms or micrograms, are each individually preincubated with 0.5  $\mu\text{g}$  of purified  $\text{Na}^+\text{-K}^+\text{-ATPase}$  at about  
15    $37^\circ\text{C}$  for about 30 minutes in a final volume of 50  $\mu\text{l}$  of preincubation mixture containing 100 mM NaCl, 3 mM  $\text{MgCl}_2$ , 50 mM tris(hydroxymethyl)aminomethane (Tris)-HCl, pH 7.4. The inhibitory activity of the test substance and HIF is measured in the presence, during preincubation, of the following chelators: 2 mM norepinephrine, 2 mg/ml BSA, and 1 mM ethylene glycol-bis ( $\beta$ -aminoethyl ether)-*N,N,N',N'*-tetraacetic  
20   acid (EGTA) to avoid interferences by vanadate, liberated fatty acids, and bivalent cations (Carilli *et al.*, *J. Biol. Chem.* 260:1027-1031, 1985). After preincubation, 40  $\mu\text{l}$  of the incubating solution are added to 1 ml of the prewarmed reading solution: 100 mM NaCl, 25 mM KCl, 6 mM  $\text{MgCl}_2$ , 1.4 mM phosphoenolpyruvate, 1 mM dithiothreitol, 20 mM *N*-2-hydroxyethylpiperazine-*N'*-2-ethanesulfonic acid (HEPES), 3 mM ATP,  
25   0.26 mM NADH, 10  $\mu\text{g/ml}$  lactate dehydrogenase, and the absorbance is recorded at about  $37^\circ\text{C}$  for at least 2 minutes. The inhibitory activity of the test substance and HIF is expressed as percent of the control sample, carried out in the same conditions but in the absence of the test substance and HIF.



-15-

Example 2: *ATP Hydrolysis Assay*

Na<sup>+</sup>-K<sup>+</sup>-ATPase activity is assayed detecting or measuring the release of <sup>32</sup>P from [<sup>32</sup>P]ATP, as previously described (Doucet *et al.*, *Am. J. Physiol.* 237:F105-F113, 1979). Test substance and HIF, typically in amounts of nanograms or micrograms, are  
5 each individually preincubated with 0.3 µg of purified enzyme for 45 minutes at about 37°C in 50 µl final volume of preincubation medium containing 140 mM NaCl, 3 mM MgCl<sub>2</sub>, 50 mM HEPES-Tis, pH 7.4. Parallel experiments are carried out, when specified, in the presence of different buffer solutions or chelators during preincubation, such as 2 mM norepinephrine, 1 mM EDTA, 1 mM EGTA, 1 mM glutathione, 5 mM  
10 mercaptoethanol and 2 mg/ml BSA. to evaluate the ionic requirements for the binding of the test substance, and to find out if, in comparison to HIF, chelators interfere with the inhibitory activity of the test substance. After the preincubation period, 10 µl of incubation solution, containing 10 mM KCl and 20 nCi [<sup>32</sup>P]ATP (0.5-3 Ci/mmol) are added, and the reaction is continued for about 15 minutes at about 37°C. The reaction is  
15 stopped by acidification with ice-cold perchloric acid solution at 30% vol/vol. <sup>32</sup>P is separated by centrifugation with activated charcoal, and radioactivity is measured by liquid scintillation counting (Beckman LS 5000 CE). The inhibitory activity of the test substance and HIF is expressed as percent of the control sample, carried out in the absence of the test substance and HIF.

20 Example 3: *Ion Transport Assay*

Purified Na<sup>+</sup>-K<sup>+</sup>-ATPase is reconstituted into phosphatidylcholine liposomes using the cholate-dialysis method disclosed by Anner and Moosmayer in *Biophys. Res. Commun.* 129:102-108, 1985. Cells containing an ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase, such as rat kidney cells or rat blood cells (erythrocytes) are prepared by the standard  
25 techniques known in the art (Shyjan and Levenson, *Biochemistry* 28:4531-4535, 1989; Carilli *et al.*, *J. Biol. Chem.*, 260:1027-1031, 1985).

Ion transport activity of the reconstituted liposomes containing an ouabain-resistant Na<sup>+</sup>-K<sup>+</sup>-ATPase, isolated kidney cells, or erythrocytes, which contain α1/β1

-16-

complex as the sole  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , is assayed by previously described methods (Anner, *et al.*, *Am. J. Physiol.*, 258:F144-F153, 1990; Cantiello, *et al.*, *Am. J. Physiol.*, 255:F574-F580, 1988; Crabos, *et al.*, *Am. J. Physiol.*, 254:F912-F917, 1988, respectively). Freshly reconstituted liposomes, isolated kidney cells or erythrocytes are  
5 washed with a physiological solution containing 140 mM NaCl, 1 mM  $\text{CaCl}_2$ , 1 mM  $\text{MgSO}_4$ , 20 mM HEPES, 5 mM  $\text{Na}_2\text{HPO}_4$  and 10 mM glucose, pH 7.5, and resuspended (Anner *et al.*, *Am. J. Physiol.* 258:F144-F153, 1990).

The test substance and HIF, typically in amounts of nanograms or micrograms, are each individually preincubated from about 30 minutes to about 3 hours at about  $0^\circ\text{C}$   
10 (liposomes), about  $37^\circ\text{C}$  (kidney cells or erythrocytes) with washed reconstituted liposomes, kidney cells or erythrocytes in a final volume of 2.5  $\mu\text{l}$  (liposomes) 50  $\mu\text{l}$  (kidney cells, erythrocytes, 25% final hematocrit in the case of erythrocytes). The preincubation is carried out both in the presence and absence of 5 mM KCl. After this period, 0.3  $\mu\text{Ci}$   $^{86}\text{RbCl}$  (1.5  $\mu\text{Ci/ml}$ ) and 5 mM KCl (when not present in the  
15 preincubation) are added. The incubation is stopped after 30 minutes by adding 100 to 500  $\mu\text{l}$  ice-cold physiological buffer solution. Parallel experiments are conducted in the absence of either the test substance or HIF, but in the presence of  $10^{-2}$  M ouabain to allow determination of ion ( $\text{Rb}^+$ ) transport activity not related to the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ . The liposomes are separated by chromatography. The kidney cells or  
20 erythrocytes are separated from the medium by rapid centrifugation through a 500  $\mu\text{l}$  phthalate oil layer, after which the tips of the tubes are sliced off and counted for  $^{86}\text{Rb}$  content (Beckman gamma counter 5500 B). The ouabain-sensitive  $^{86}\text{Rb}$  uptake is calculated as the difference between the Rb uptake in the absence and presence of  $10^{-2}$  M ouabain.

25 While this invention has been particularly shown and described with reference to certain embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

-17-

## CLAIMS

What is claimed is:

1. A method for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , comprising the steps of:
  - 5 (a) contacting the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with the test substance under suitable conditions for measuring or detecting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity;
  - (b) measuring or detecting the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  inhibitory activity of the test substance; and
  - 10 (c) comparing the level of activity of the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  measured or detected in step (b) with the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity measured or detected in the presence of HIF under comparable conditions, thereby determining whether the test substance exhibits HIF inhibitory activity.
- 15 2. The method of Claim 1, further comprising the step of contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF under suitable conditions in an aqueous medium for ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity, wherein said activity is measured or detected, thereby providing the measurement or detection to be compared to the measurement or detection of the test substance.
- 20 3. A method for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , comprising the steps of:
  - (a) contacting the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with the test substance in the presence of ATP and a non-ATP substrate, under suitable conditions for measuring or detecting oxidation of the non-ATP  
25 substrate;

-18-

- (b) measuring or detecting the oxidation of the non-ATP substrate; and  
(c) comparing the measured or detected oxidation of the non-ATP substrate with measured or detected oxidation of the non-ATP substrate contacted with ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  in the presence of HIF and ATP under comparable conditions, thereby determining whether the test substance exhibits HIF inhibitory activity.
- 5
4. The method of Claim 3, further comprising the step of contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity with HIF under suitable conditions in an aqueous medium for ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity, wherein said activity is measured or detected, thereby providing the measurement or detection to be compared to the measurement or detection of the test substance.
- 10
5. A method for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , comprising the steps of:
- (a) contacting the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with the test substance in the presence of ATP, wherein the terminal phosphate ( $\text{P}_3$ ) is labeled, under suitable conditions for measuring or detecting liberated labeled  $\text{P}_3$ ;  
(b) measuring or detecting liberated labeled  $\text{P}_3$ ; and  
(c) comparing the measured or detected liberated labeled  $\text{P}_3$  with the measured or detected labeled  $\text{P}_3$  that is liberated by contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF in the presence of ATP, wherein the terminal phosphate is labeled, under comparable conditions, thereby determining whether the test substance exhibits HIF inhibitory activity.
- 15
- 20
6. The method of Claim 5, further comprising the step of contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF under suitable conditions in an aqueous medium for ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity, wherein said activity is
- 25

measured or detected, thereby providing the measurement or detection to be compared with the measurement or detection of the test substance.

7. An assay for screening a test substance for HIF inhibitory activity of an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , comprising the steps of:

- 5 (a) contacting liposomes containing, or cells expressing or containing, the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with the test substance in the presence of a compound comprising isotopic  $\text{Rb}^+$ , under suitable conditions for isotopic  $\text{Rb}^+$  uptake by the liposomes or the cells;
- 10 (b) measuring or detecting the amount of the isotopic  $\text{Rb}^+$  present in the liposomes or the cells; and
- (c) comparing the isotopic  $\text{Rb}^+$  present in the liposomes or cells measured or detected with measured or detected isotopic  $\text{Rb}^+$  obtained by contacting liposomes containing, or cells containing or expressing, ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF in the presence of a compound comprising isotopic  $\text{Rb}^+$ , under comparable conditions, thereby determining whether
- 15 the test substance exhibits HIF inhibitory activity.

8. The method of Claim 7, further comprising the step of contacting ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with HIF under suitable conditions in an aqueous medium for ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  activity, wherein said activity is
- 20 measured or detected, thereby providing the measurement or detection to be compared with the test substance.

9. The method of Claim 1, 3, 5 or 7, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is selected from the group consisting of a rodent, toad and butterfly  $\alpha 1$   $\text{Na}^+\text{-K}^+\text{-ATPase}$ .

-20-

10. The method of Claim 9, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is a rat kidney  $\alpha 1$  ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ .
11. The method of Claim 9, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is a *Bufo marinus*  $\alpha 1$  ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ .
- 5 12. The method of Claim 9, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is a *Danaus plexippus*  $\alpha 1$   $\text{Na}^+\text{-K}^+\text{-ATPase}$ .
13. The method of Claim 1, 3, 5 or 7, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is obtained by substituting one or both border amino acid residues of the H1-H2 extracellular domain of  $\alpha$  subunit of an ouabain-sensitive  $\text{Na}^+\text{-K}^+\text{-ATPase}$  with a  
10 charged amino acid residue.
14. The method of Claim 3, wherein the non-ATP substrate is NADH.
15. The method of Claim 3, wherein the oxidation level of the non-ATP substrate is measured by a decrease of the amount of the non-ATP substrate.
16. The method of Claim 14, wherein the oxidation of NADH is measured by a  
15 decrease of the amount of NADH.
17. The method of Claim 16, wherein the decrease of the amount of NADH is measured by a decrease in absorbance at 340 nm.
18. The method of Claim 5, wherein the ATP is labeled with a label selected from the group consisting of a radiolabel, a fluorescent label, a luminescent label and  
20 an enzymatic label.

-21-

19. The method of Claim 18, wherein the labeled ATP is [ $^{32}\text{P}$ ]ATP.
20. The method of Claim 5, wherein the liberated, labeled  $\text{P}_3$  is separated from the reaction mixture.
21. The method of Claim 20, wherein the separation is by centrifugation.
- 5 22. The method of Claim 21, wherein the centrifugation is carried out in the presence of activated charcoal.
23. The method of Claim 19, wherein the amount of the liberated labeled  $^{32}\text{P}$  is measured by liquid scintillation counting.
24. The method of Claim 7, wherein the isotopic  $\text{Rb}^+$  is  $^{86}\text{Rb}^+$ .
- 10 25. The method of Claim 7, wherein the isotopic  $\text{Rb}^+$  present in the liposomes containing the ouabain-resistant  $\text{Na}^+/\text{K}^+$ -ATPase is separated from the unincorporated or liberated compound comprising isotopic  $\text{Rb}^+$  by chromatography.
- 15 26. The method of Claim 7, wherein the isotopic  $\text{Rb}^+$  present in the cells containing the ouabain-resistant  $\text{Na}^+/\text{K}^+$ -ATPase is separated from the unincorporated or liberated compound comprising isotopic  $\text{Rb}^+$  by centrifugation through an oil layer.
27. The method of Claim 26, wherein the oil layer is a phthalate oil layer.

-22-

28. The method of Claim 24, wherein the amount of  $^{86}\text{Rb}^+$  present in the liposomes or the cells containing the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is measured by a gamma counter.
29. The method of Claim 1, 3, 5 or 7, wherein the HIF is isolated from bovine hypothalamus.
30. The method of Claim 1, 3, 5 or 7, wherein the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  is isolated from a target cell.
31. The method of Claim 30, wherein the target cell is selected from the group consisting of a kidney cell, a heart cell, a pineal gland cell, a skeletal muscle cell, a retina horizontal cell, a retina Muller cell, a brain cortical astrocyte, a cerebellar granule neuron, a cortical neuron and a Hippocampal neuron.
32. The method of Claim 30, wherein the target cell is derived from a patient exhibiting a disease state that is related to dysfunction of the ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$  in said target cell, thereby determining whether said target cell will respond to the test substance.
33. The method of Claim 32, wherein the disease state is selected from the group consisting of a cardiac malfunction in which a treatment to produce a positive inotropic effect is desired or needed. an edematous disorder and hypotension.
34. The method of Claim 33, wherein the cardiac malfunction is selected from the group consisting of congestive heart failure, paroxysmal atrial tachycardia and atrial fibrillation.



-23-

35. The method of Claim 33, wherein the edematous disorder is selected from the group consisting of congestive heart failure, cirrhosis of the liver and nephrotic syndrome.
36. A kit, comprising:
- 5 (a) an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ , or reconstituted liposomes or cells containing an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ;
- (b) HIF;
- (c) a non-ATP substrate of said isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ;
- (d) ATP or labeled ATP; and
- 10 (e) a compound containing isotopic  $\text{Rb}^+$ .
37. A kit comprising:
- (a) an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ;
- (b) ATP;
- (c) NADH; and
- 15 (d) HIF.
38. A kit comprising:
- (a) an isolated ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ;
- (b) ATP in which the  $\text{P}_\beta$  is labeled; and
- (c) HIF.
- 20 39. A kit, comprising:
- (a) reconstituted liposomes containing, or cells containing or expressing, an ouabain-resistant  $\text{Na}^+\text{-K}^+\text{-ATPase}$ ;
- (b) a compound containing isotopic  $\text{Rb}^+$ ; and
- (c) HIF.

-24-

40. A biologically active substance identified by the method of Claim 1, 3, 5 or 7.
41. A method of treating or preventing a disease or disorder which comprises administering, to a subject to which such treatment or prevention is needed, an effective amount of a biologically active substance identified by the assay of  
5 Claim 1, 3, 5 or 7, as exhibiting HIF inhibitory activity.
42. The method of Claim 41, wherein the disease or disorder is selected from the group consisting of a cardiac malfunction in which a treatment to produce a positive inotropic effect is desired or needed, an edematous disorder and hypotension.

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/29845

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C12Q1/42 G01N33/58 G01N33/58 A61P9/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C12Q G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	S. P. JANSSENS ET AL.: "Hypothalamic Na <sup>+</sup> , K <sup>+</sup> -ATPase inhibitor constricts pulmonary arteries of spontaneously hypertensive rats." JOURNAL OF CARDIOVASCULAR PHARMACOLOGY, vol. 22, no. suppl. 2, 1993, pages S42-S46, XP000901477 New York, US. the whole document	1,3,5,7, 36-42
A	C. DE ANGELIS ET AL.: "Hypoxia triggers release of an endogenous inhibitor of Na <sup>+</sup> -K <sup>+</sup> -ATPase from midbrain and adrenal." AMERICAN JOURNAL OF PHYSIOLOGY, vol. 274, no. 1, January 1998 (1998-01), pages F182-F188, XP000901115 the whole document	1,3,5,7, 36-42
	-/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"G" document member of the same patent family

Date of the actual completion of the international search

26 May 2000

Date of mailing of the international search report

07/06/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Griffith, G

## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 99/29845

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	J. M. SANCHO: "A non-ouabain Na/K ATPase inhibitor isolated from bovine hypothalamus. Its relation to hypothalamic ouabain." CLINICAL AND EXPERIMENTAL HYPERTENSION, vol. 20, no. 5 & 6, July 1998 (1998-07), pages 535-542, XP000901480 the whole document	1,3,5,7, 36-42
A	WO 98 53832 A (THE GENERAL HOSPITAL CORPORATION) 3 December 1998 (1998-12-03) the whole document	40-42
A	WO 97 19099 A (LOMA LINDA UNIVERSITY MEDICAL CENTER) 29 May 1997 (1997-05-29) the whole document	40-42
A	M. L. CROYLE ET AL.: "Extensive random mutagenesis analysis of the Na <sup>+</sup> /K <sup>+</sup> -ATPase alpha subunit identifies known and previously unidentified amino acid residues that alter ouabain sensitivity." EUROPEAN JOURNAL OF BIOCHEMISTRY, vol. 248, no. 2, September 1997 (1997-09), pages 488-495, XP000905100	

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/US 99/29845

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9853832 A	03-12-1998	US 5910484 A AU 7603598 A EP 0983071 A	08-06-1999 30-12-1998 08-03-2000
WO 9719099 A	29-05-1997	AU 1123197 A	11-06-1997